Climate and environmentally friendly solar cooling technology solutions

Green Cooling Webinars #4

27 August 2025 l 12 – 1 pm UTC

Netiquette

Mute yourself to minimize background noise.

Use the "raise hand" feature or chat function to indicate when you have a question or want to contribute to the conversation.

Please feel free to write any questions in the chat.

Agenda

Time (UTC)	Topic	Speaker
12:00-12:05	Opening Remarks	Ellen Michel, GIZ Proklima
12:05-12:40	Climate and environmentally friendly solar cooling technology solutions	Philipp Denzinger, GIZ Proklima
12:40-13:00	Q&A	All participants

Welcome Remarks

Ellen Michel
Project Manager GCI III, GIZ PROKLIMA

Climate- and Environmentally-friendly Solar Cooling Technology Solutions

Philipp Denzinger, GIZ Proklima

Green Cooling Webinar No. 4, 27.08.2025

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Agenda

- Background Proklima
- Introduction
- Climate and Environmental Impact of Refrigerants and of Batteries
- Solar Cooling Technologies (Refrigeration)
- Solar Cooling Technologies (Air-Conditioning)
- Conclusions
- Further Readings

GIZ Proklima core expertise

- Programme established in 1995 in the context of implementing technical projects for **ozone protection** under the Montreal Protocol. In 2016, the Kigali Amendment broadened the focus from ozone to **climate protection**.
- Proklima is working on behalf of **German Ministries (BMZ, BMUKN, BMWK)** and other donors, e.g. EU, AFD, Defra, NAMA…
- Goal: promoting and introducing **natural refrigerants and energy-efficient appliances** in the **RAC sector**.

Policy Advice

Support for comprehensive **mitigation approaches in the cooling sector**

Technology Transfer

Cooperation with the private sector (e.g. production and demonstration of climate-friendly air conditioning systems)

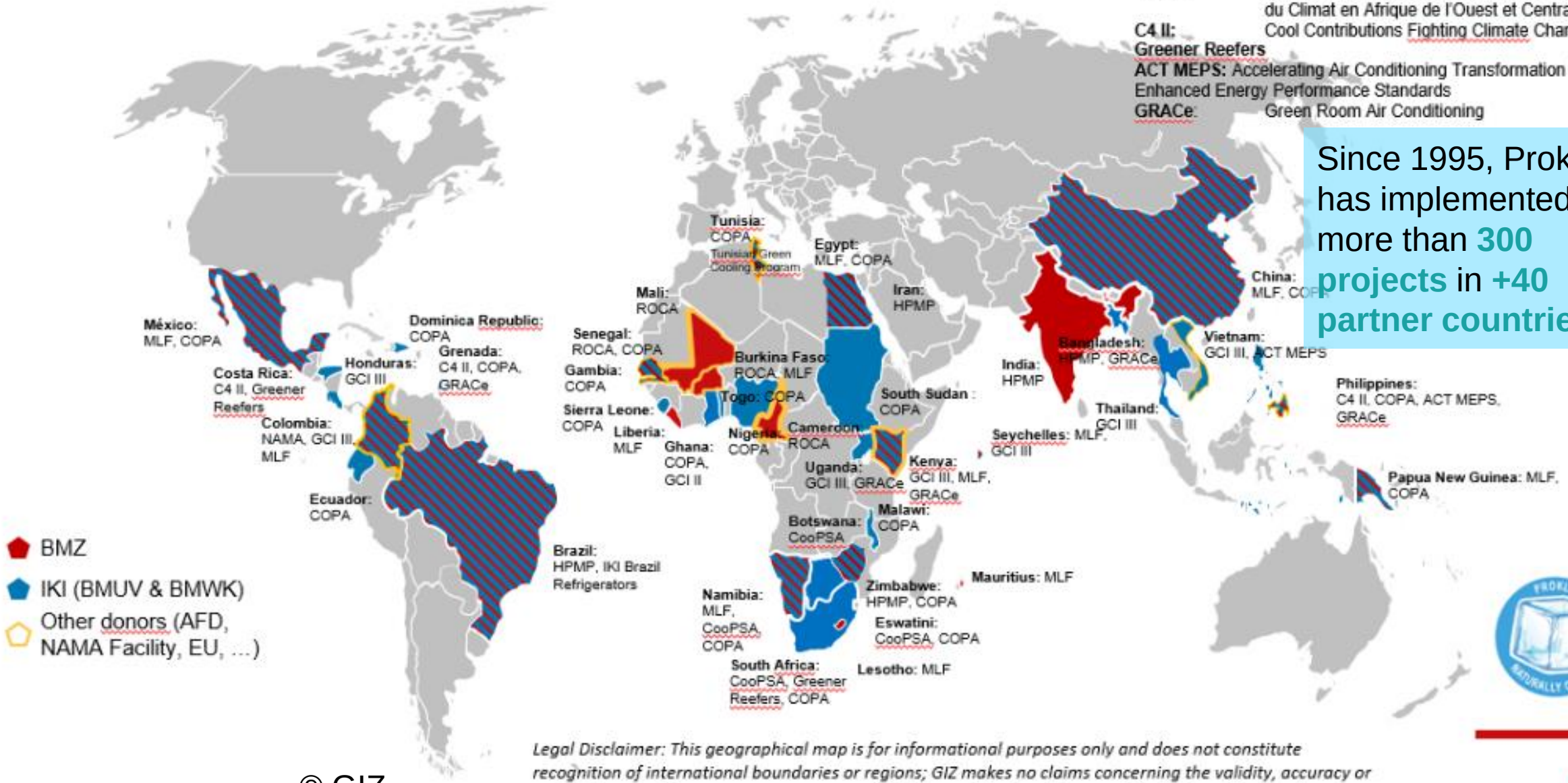
Capacity Building

Enabling the spread of Green Cooling technologies worldwide by providing **training on best practices and the safe handling of natural refrigerants**

Portfolio GIZ Proklima (03/2025)

COPA: Climate and Ozone Protection Alliance
GCI III: Green Cooling Initiative III
CooPSA: Cooling Programme Southern Africa
MLF: Multilateral Fund of the Montreal Protocol (ozone fund)
ROCA: Refroidissement respectueux de l'Ozone et du Climat en Afrique de l'Ouest et Centrale
C4 II: Cool Contributions Fighting Climate Change
Greener Reefers
ACT MEPS: Accelerating Air Conditioning Transformation through Enhanced Energy Performance Standards
GRACe: Green Room Air Conditioning

Since 1995, Proklima has implemented more than **300 projects** in **+40 partner countries**



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Strategic Focus Approach: "Leapfrogging" to Green Cooling

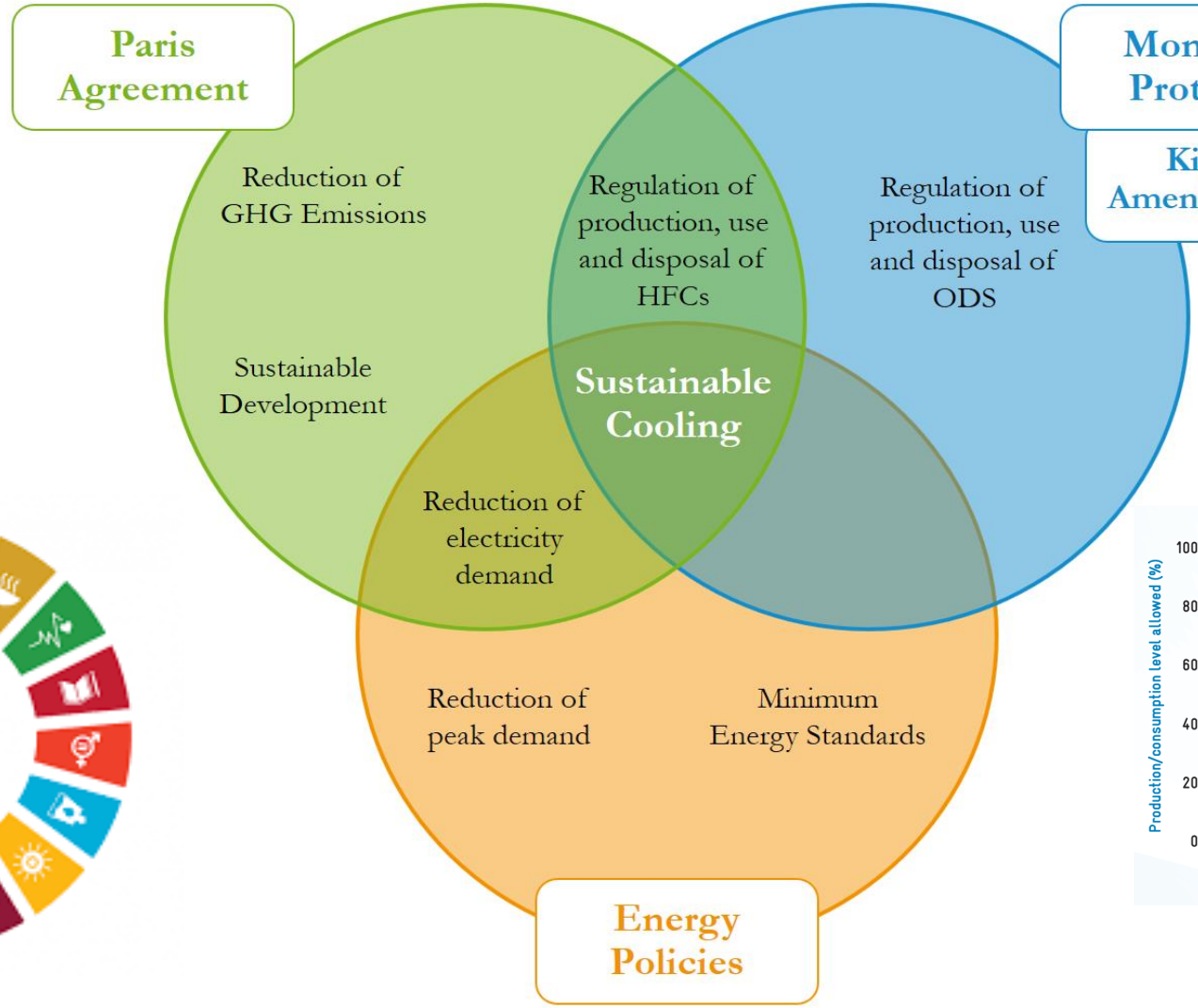
Concept of Green Cooling:

- Natural refrigerants
- Highly energy efficient appliances
- Ideally powered by renewable energy sources (solar cooling)

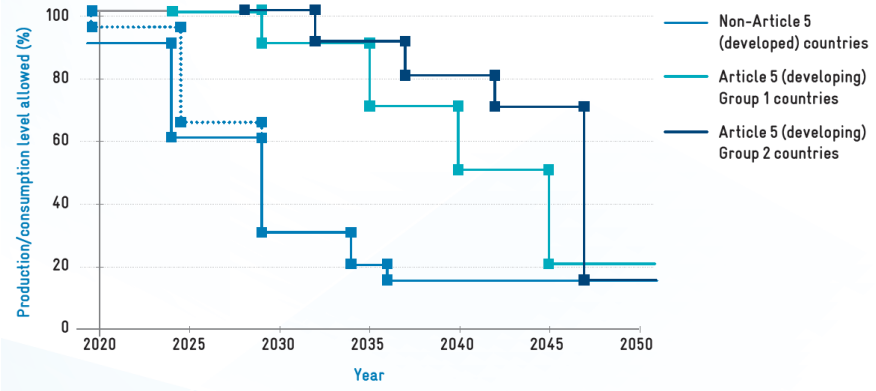
Instant switch to Green Cooling

- Avoid another conversion to interim technologies
- Avoid the lock-in of large amounts of HFC banks
- Technology options for natural refrigerants available for all RAC subsectors
- Facilitate enabling environment for natural refrigerants, e. g. safety standards

Combination of Paris Agreement and Montreal Protocol



Kigali Amendment Schedule



The Importance of Solar Cooling in the Global Cold Chain

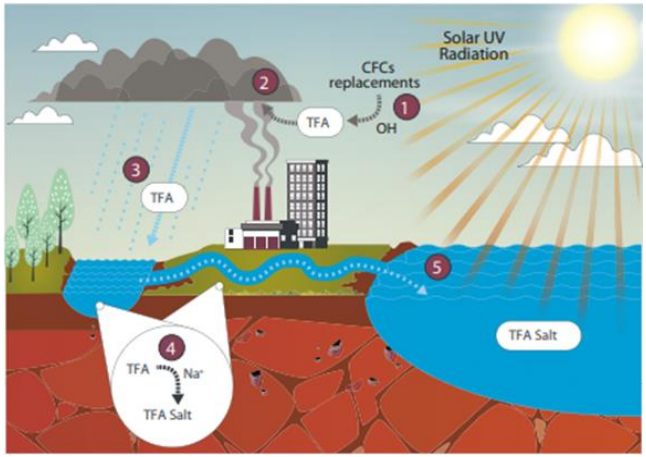
- Cold chain emissions - ~ 2% of global greenhouse gas emissions (GHG) (Peters et al. 2020)
- Food loss: 931 million tonnes in 2019 – 17% of total food produced (FAO 2019)
- Only 45% of food requiring refrigeration is actually refrigerated (IIR)
- 12% of agricultural production for human consumption is lost due to insufficient refrigeration (UNEP 2021)
- These losses lead to ~1,004 million tons of avoidable CO_2 emissions (FAO 2019)
- 822 million people lack refrigerators (60% of sub-Sahara Africa´s population) (Efficiency for Access Coalition 2023)
- Lack of access to cooling is a significant risk for 1.2 billion people in poor rural and urban settings worldwide, with 28 million more people at high risk compared to 2021 (Efficiency for Access Coalition 2023)

Solar cooling technologies can provide reliable, inclusive refrigeration in areas with poor electricity access and can reduce postharvest losses, enhance livelihoods, and cut GHG emissions.

Climate and Environmental Impact of Refrigerants

Refrigerant	Type	Composition	Alternative for[29]	GWP 20	GWP 100	Flammability	PFAS	TFA
R22[30]	HCFC	Pure		**5960**	**1960**	**A1**	**No**	**No**
R404A	HFC blend	R143a (52%) R125 (44%) R134a (4%)	R22, R502	**7208**	**4728**	**A1**	**Yes (R125, R134a, R143a)**	**R134a (20%) R143a (10%)**
R410A	HFC blend	R32 (50%) R125 (50%)	R22, R13B1	**4850**	**2256**	**A1**	**Yes (R125)**	**No**
R407F	HFC blend	R134a (40%), R125 (30%), R32 (30%)	R22, R404A	**4566**	**1965**	**A1**	**Yes (R134a, R125)**	**R134a (20%)**
R134a	HFC	Pure	R12, R22	**4140**	**1530**	**A1**	**Yes (R134a)**	**R134a (20%)**
R449A	HFC/HFO blend	R134a (25.7%) R1234yf (25.3%) R125 (24.7%) R32 (24.3%)	R404A, R507A	**3448**	**1504**	**A1**	**Yes (R125, R134a, R1234yf)**	**R134a (20%) R1234yf (100%)**
R32	HFC	Pure	R134a, R407A, R410A	**2960**	**771**	**A2L**	**No**	**No**
R454C	HFC/HFO blend	R1234yf (78,5%) R32 (21.5%)	R404A, R410A	**638**	**166**	**A2L**	**Yes (R1234yf)**	**R1234yf (100%)**
R1234yf	HFO	Pure	R407A, R410A, R134a	**1.81**	**0.501**	**A2L**	**Yes (R1234yf)**	**R1234yf (100%)**
R744	CO_2	Pure	R134a, R404A, R407A, R410A, R22	**1**	**1**	**A1**	**No**	**No**
R717	Ammonia NH_3	Pure	R134a, R404A, R407A, R410A, R22	**0**	**0**	**B2L**	**No**	**No**
R170	HC ethane	Pure	R23, R508B	**1.57**	**0.437**	**A3**	**No**	**No**
R600a	HC isobutane	Pure	R134a, R12	**0,06**	**0,02**	**A3**	**No**	**No**
R290	HC propane	Pure	R134a, R404A, R407A, R410A, R22, R502	**0.072**	**0.02**	**A3**	**No**	**No**

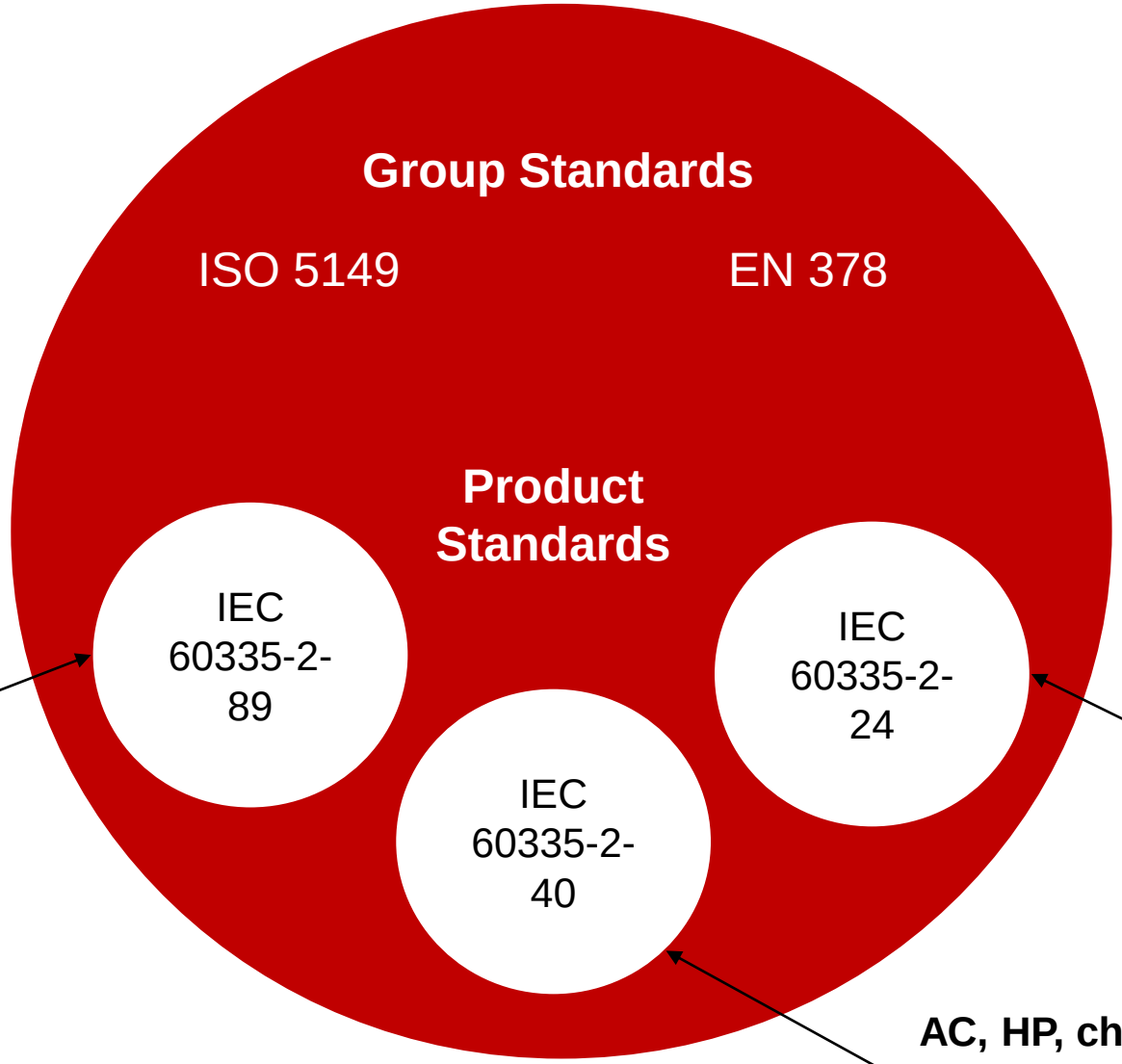
Per- and polyfluoroalkyl substances (PFAS) are a large class of synthetic chemicals that increasingly detected as environmental pollutants and linked to negative effects on human health. **Trifluoroacetic acid (TFA)** is an ultra short chain type of PFAS, commonly found in the breakdown of f-gases.



These substances are not manageable, and all efforts should be undertaken to avoid them as completely as possible

Sources:
Smith et al. (2021) The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity Supplementary Material. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.
World Meteorological Organization (2022) Scientific Assessment of Ozone Depletion: 2022.
Everitt, N. (2023) PFAS ban affects most refrigerant blends. Cooling Post.
Behringer et al. (2021) Persistent degradation products of halogenated refrigerants and blowing agents in the environment: type, environmental concentrations, and fate with particular regard to new halogenated substitutes with low global warming potential.
Linde Industrial Gases (n.d.) Refrigerants.

Safety Standards



Commercial refrigeration
Up to 500g of R290 charge

Domestic refrigeration
Up to 150g R600a charge

AC, HP, chillers
Up to 1 kg R290 and 1.2 kg R1270 charge for direct systems (split) and no limitation for indirect systems

Climate and Environmental Impact of Batteries

Estimated climate impact from Li-ion batteries manufacturing: **from 39 kg CO2eq./kWh to 196 kg CO2eq./kWh**

➔ **embedded CO2 emissions** from manufacturing one 1000Ah battery (for a 21m³ walk-in cold room) = 2,950km - 22,350km driven by a diesel car consuming 5l per 100 km

➔ Additional emissions are caused due to shipment of batteries

➔ Most countries do not have adequate battery recycling capacities, which leads towards a negative environmental impact at end of life

➔ Batteries are expensive and need to be replaced usually after 6 years, which can harm sustainability.

➔ **Consequently, thermal storage solations (e.g. ice storage) should be chosen, if possible.**

Type	Approx. purchasing price (120Ah battery)	Type Expected lifetime (years)	Recyclability	Complexity of recycling	Profitability of recycling	Toxicity potential	Safety risk in use-phase
Lithium-ion	high (≈ 750 USD)	10-15	Medium	High	Very low	Medium	Low
Lead-acid: Gel	low (≈ 200 USD)	Up to 6	Very high	Medium	High	Very high	Medium
Lead-acid: AGM	Low (≈ 175 USD)	Up to 6	Very high	Low-medium	High	Very high	Medium
Lead-acid: flooded	very low (≈ 110 USD)	3-5	Very high	Low-medium	High	Very high	Medium / High

Solar Cooling Technologies

Application	Technology	Type of solar	Direct drive	Type of storage
Refrigeration	Walk-in cold room	PV	Yes/no	Ice storage and/or batteries
	Fridge	PV	Yes/no	Ice storage and/or batteries
	Freezer	PV	Yes/no	Ice storage and/or batteries
	Ice production (e.g. fish cooling)	PV	Yes/no	Ice storage and/or batteries
	Milk cooling	PV	Yes/no	Ice storage and/or batteries
	Chiller	PV (compression chiller)	Yes/no	Batteries
		Thermal (absorption chiller)	-	Thermal (hot water tank storage or ice storage)
Air conditioning	Chiller	PV (compression chiller)	Yes/no	Batteries
		Thermal (absorption chiller)	-	Thermal (hot water tank or ice storage)
	Split air conditioner	PV	Yes/no	Batteries (soon: with ice storage)

Climate- and Environmentally-friendly Solar Refrigeration

Solutions and Case Studies

Stationary Solar R290 Ice Maker in Indonesia

up to 245 tons of ice production from local resources per year → virtually anywhere

250-500 tons of fish additionally on ice (1:1 or 2:1 fish to ice ratio)

© Romain Metaye

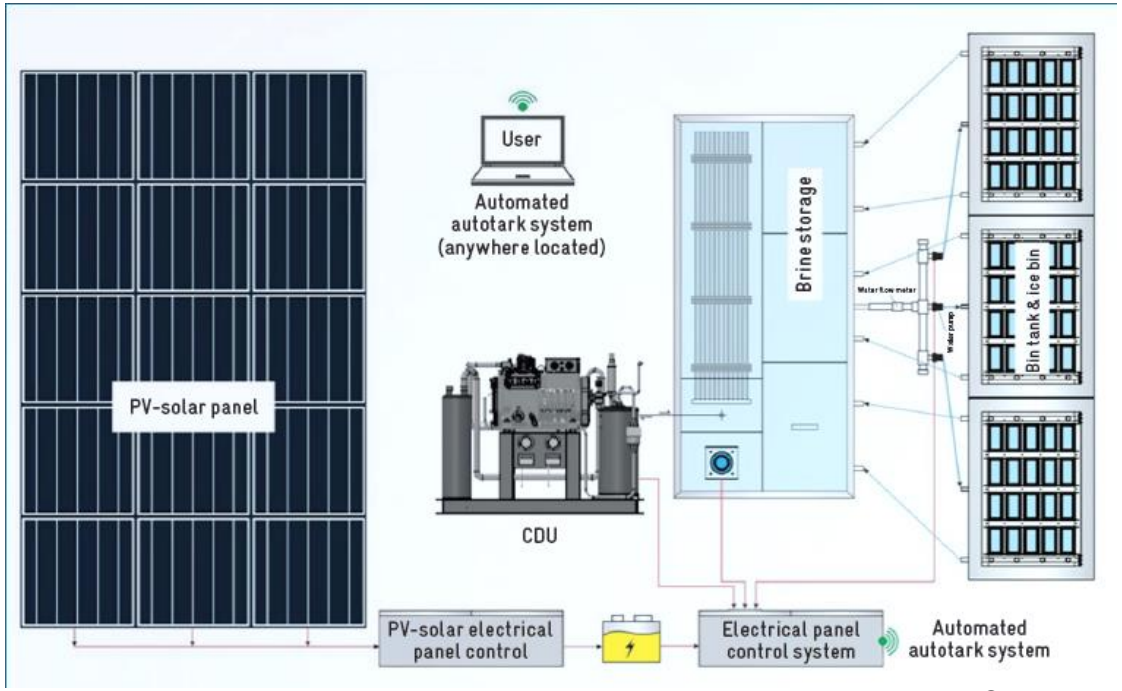
- ✓ **70,000-140,000 USD p.a. additional value locally**
- ✓ **Enabling market access**
- ✓ **Cooperative model: higher bargaining power**
- ✓ **Preventing food spoilage**

avoided costs for block ice from Diesel power

- 14,290 liters of Diesel fuel per year
- USD 10,000 in direct fuel costs
- 40 tons of CO_2 per year

R290 Solar Ice Maker with Ice Storrage in Indonesia

© GIZ Indonesia/Frank Stegmüller

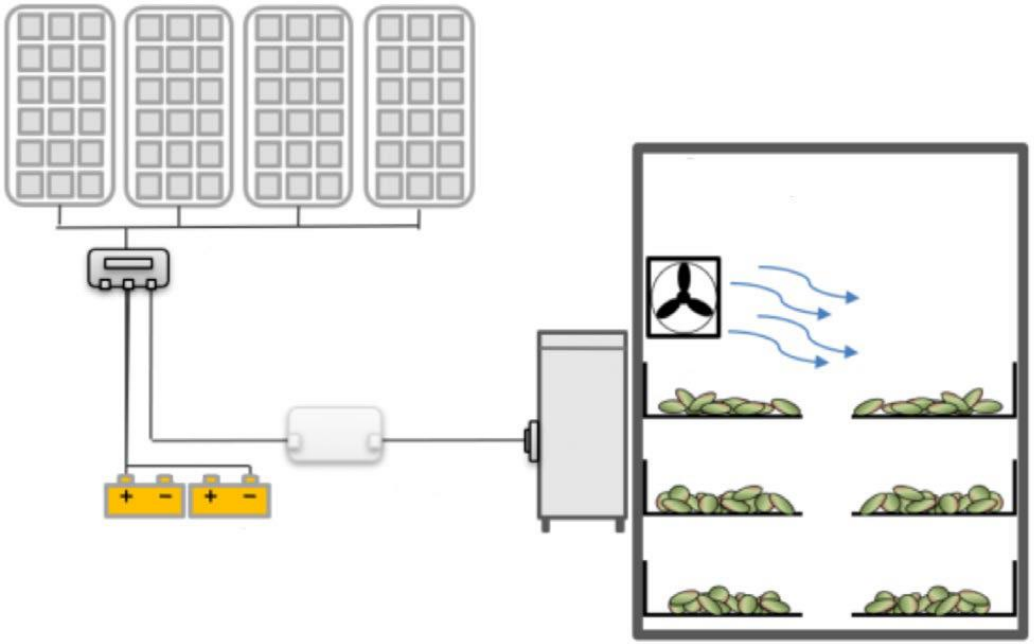


© IPNLF

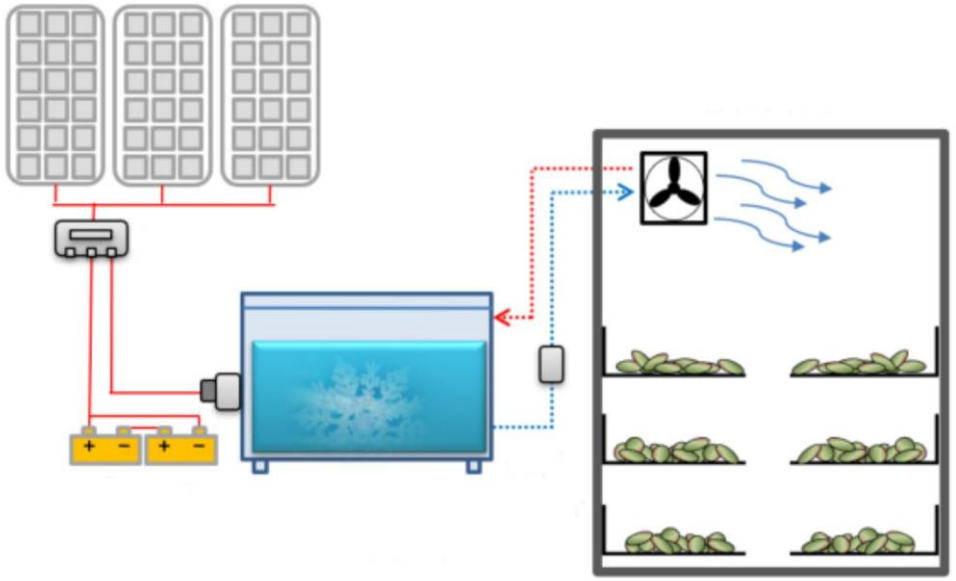
Parameter	Description
Ice Production	1.2 tons per day
Ice Storage	20 Ft container
Refrigerant and charge	R290
GWP 100 years / 20 years (IPCC AR6)	0.02 / 0.072

Walk-In Solar Cold-Rooms

Conventional solar cooling system



SelfChill solar cooling system without direct drive



© Solar Cooling Engineering

ColdHubs Nigeria

© ColdHubs /Nnaemeka Ikegwuonu

- 24/7 off-grid storage and preservation of perishable foods
- “plug and play” modular
- Using natural refrigerant R290 (monobloc)
- 120mm insulating cold room panels retain the cold
- Batteries + inverter (newer generation with ice storage)
- Pay-as-you-store subscription model
- Around 100 units installed in Nigeria

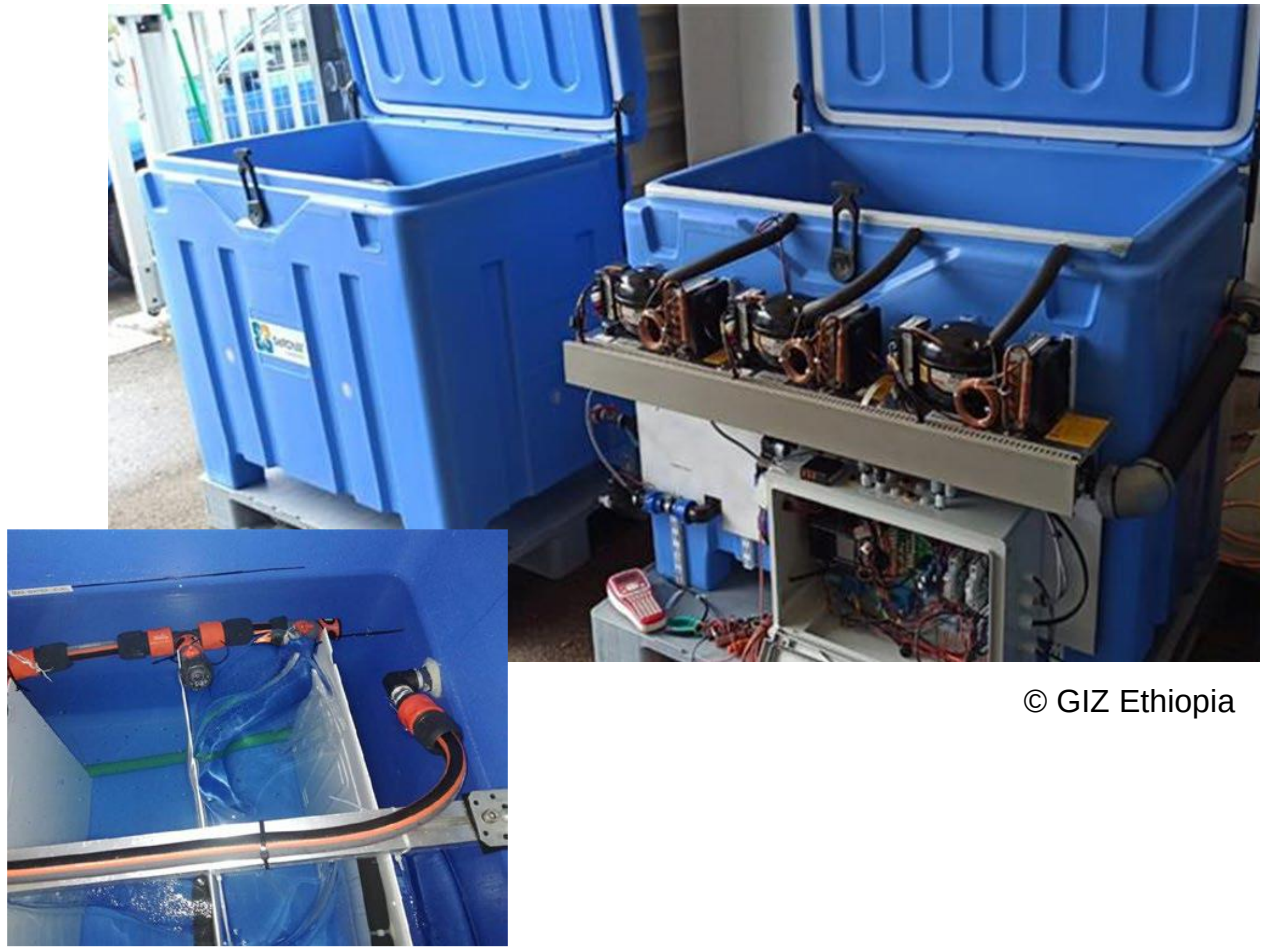
➢ **Extend shelf life of perishable goods from 2 to 21 days**
➢ **Reducing post-harvest loss by 80 percent**

Water Chilled Cooling Units in Kenya and Togo (SelfChill)

Cold rooms with 12 SelfChill units in the direct drive configuration

- SelfChill = solar-powered water chillers
  One cooling unit can create up to 30 kg of ice in one day, per water chiller while the cooling unit is inactive

➢ Target group: smallholder farmers in Kenya and Togo
➢ Sustainable and cost-effective way to preserve products and significantly reduce post-harvest losses due to high ambient temperatures



© GIZ Ethiopia

Water Chilled Cooling Units in Kenya and Togo (SelfChill)

Parameter	Description
Cold Cell Dimensions	3,3 x 3,3 x 2,2 m (21.5 m3)
Cooling Capacity	12 x 200 W = 2400 W (2.4 kW)
Ice Storage	600kg, which represents 700 W of cooling power (72 hours of autonomy)
GWP 100 years / 20 years (IPCC AR6)	0.02 / 0.06
Refrigerant and charge	R600a (12 x 35g = 420g)
PV Capacity (cooling units – direct connection, ice storage)	5 kWp (East – West orientation)
PV Capacity (water pump and heat exchanger, fan coil)	400 Wp
Battery capacity (only for water pump and heat exchanger)	160 Ah
Heat Exchanger (fan coil)	29 W energy consumption (1.2 kW cooling power)
Ambient Temperature / Min. achievable Cold Room Temperature	25 °C / 4 °C 35 °C / 6 °C 45 °C / 8 °C

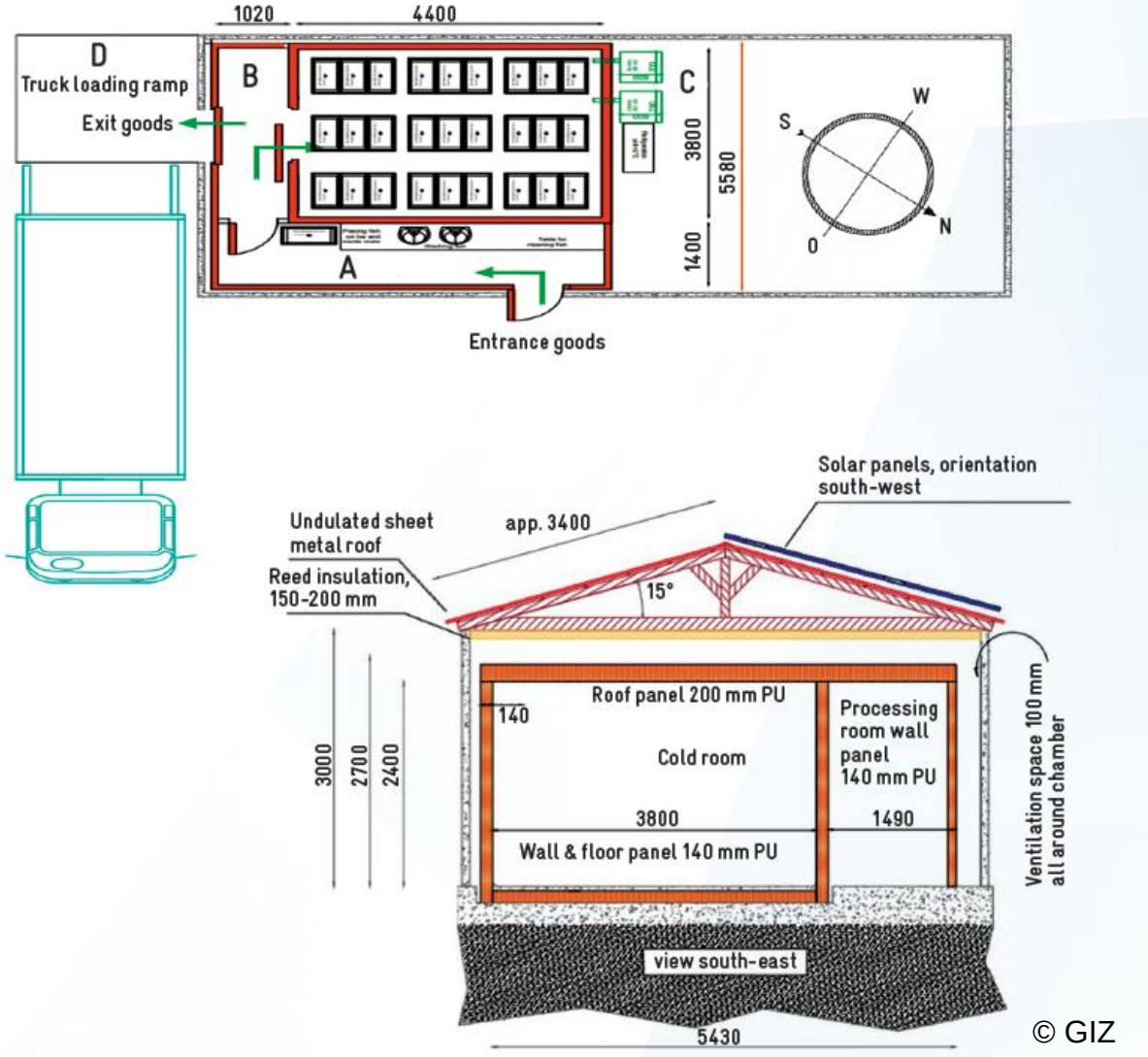
© Strathmore Energy Center, Kenya

Solar Fish Cold Store in Mfangano Island, Homa Bay County in Lake Victoria, Kenya

Pilot project of a fish cold room through co-investment for small-scale fishermen for cooling their catches

Processing area for embedding the fish in ice flakes and refrigeration unit

- With state-of-the-art insulation, highly efficient refrigeration (monoblock) and ice-making (ice flakes) appliances using the natural refrigerant R290
- Able to store an economic quantity of fish to be caught daily on the appropriate cooling near 0°C



Solar Fish Cold Store in Kenya

Parameter	Description
Dimensions (L x W x H)	4.4 x 3.8 x 2.4 m
Volume	40.1 m3 plus Anteroom of 9.30 m3
Total Cooling Capacity	1.9 kW (< 5 kW)
Ice Storage	600kg, which represents 700 W of cooling power (72 hours of autonomy)
Refrigerant	R290 (propane)
Refrigerant charge	118 g (ice maker) and 150 g (monoblock)
GWP 100 years / 20 years (IPCC AR6)	0.02 / 0.072
Power supply	100% PV
Total peak power consumption	2.6 kW
PV module type	260 W, 1665 x 991 mm, 15° tilt angle
Total PV peak power	2.6 – 3.12 kW (calculated)
Energy storage	Electrical Battery (Deep cycle 12V)
Ice bank type	Ice maker
Ice bank power	0.8 kW
Ice bank capacity	230 kg ice per day / 19.2 kWh (calculated)
Total autonomy period	10 hours (calculated)
Inverter	Off grid – two phases

© creative republic

Solar-Powered Cold Rooms in Ethiopia

Project Green People's Energy aimed to test solar-powered cooling systems in rural horticultural cooperatives benefiting over 1.400 farmers directly and indirectly

- Six solar PV-powered cooling containers from Frigos Indus
- Used for cooling goods during the day and freezing water for night-time cooling
- Requires only a small battery for air circulation and control units, operating between 4 and 15 degrees Celsius .

© GIZ Ethiopia

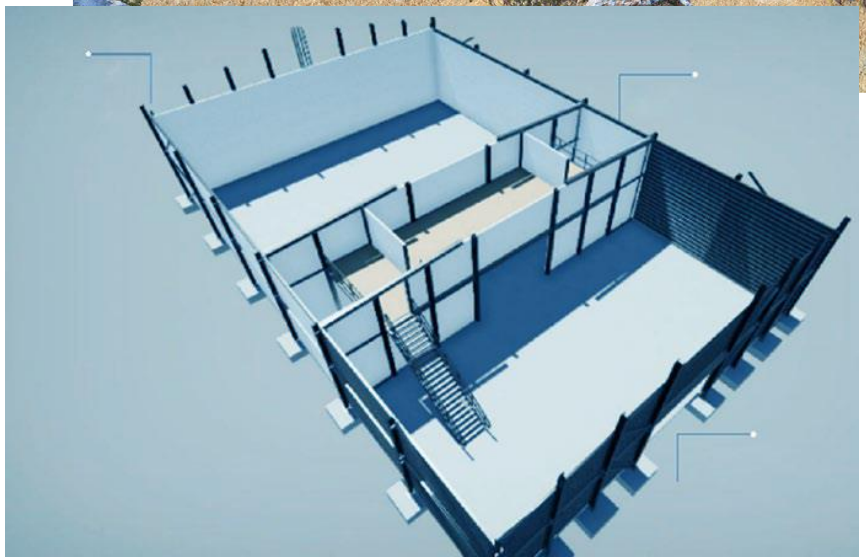
Solar-Powered Cold Rooms in Ethiopia

Parameter	Description
Volume	17.2 m3 (20" Container)
Dimensions (L x W x H)	3.9 x 2.1 x 2.1 m
Cold Room Temperature	4-15 °C
Total Cooling Capacity	2.23 kW
Refrigerant	R290
GWP 100 year / 20 years (IPCC AR6)	0.02 / 0.072
Total Peak Power Consumption	4.4 kW
PV Moduls	12 400 W monocrystalline moduls
Total PV Peak Power	4.8 kW
Energy Storage	Electrical and thermal
Battery Type	Cobalt free lithium iron phosphate (LFP)
Battery Capacity	5.12 kWh
Total Autonomy period	12 hours

Large Solar PV-Powered Warehouse-Scale Walk-In Cold Room using NH3

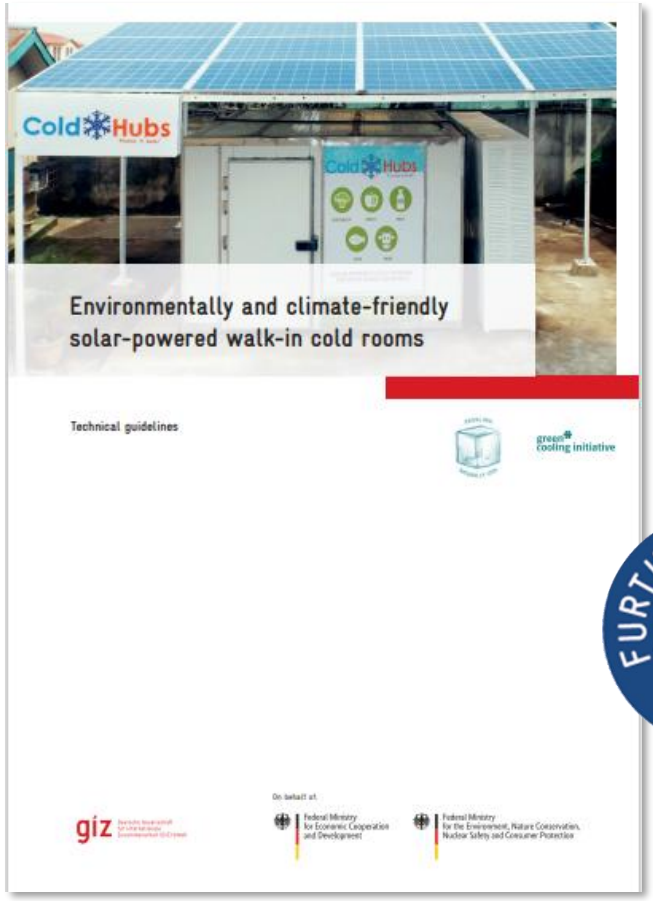
Turnkey warehouse-scale walk-in cold rooms by Off-Grid Europe GmbH

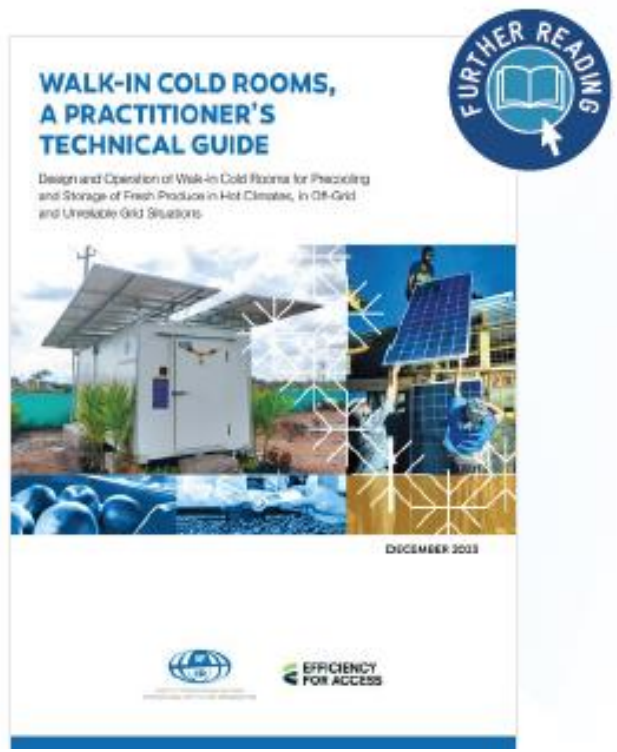
- based on a steel mounting structure for solar panels & 100% powered by solar PV and integrated with a battery energy storage system (BESS)
- Offers variable temperatures (6-14 °Celsius) for different agricultural good that can be adjustable to different seasons
- Refrigeration system is using ammonia (NH3) as refrigerant



Walk-In Solar Cold-Rooms

Further Reading: Guidelines for environmentally and climate-friendly solar-powered walk-in cold rooms





Solar Milk Cooling in Ethiopia

© GIZ

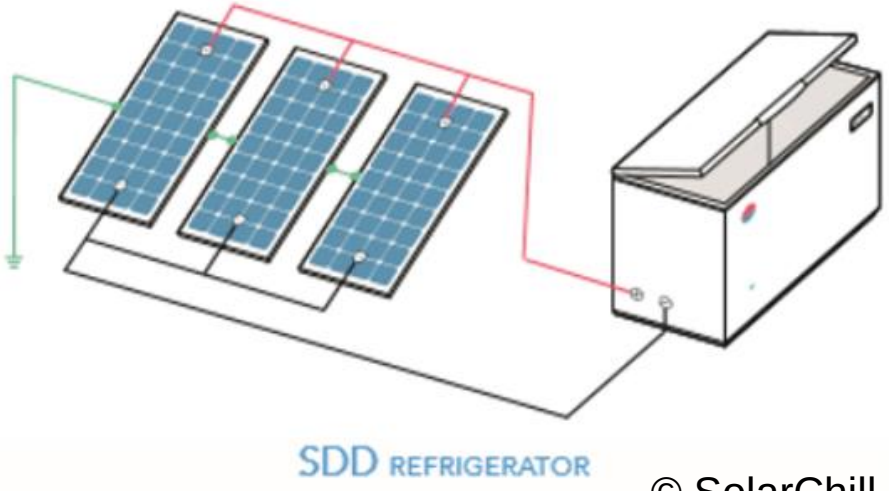
Solar-powered milk cooling system developed by Selfchill at the Denkaka Dairy Cooperative near Bishoftu town implemented as part of the GIZ SEFFA EnDev project

- Solar PV power to produce ice on evaporator plates -> used to cool water -> chilled water is pumped into a bath containing stainless steel milk cans
- **Refrigerant**: R600a

→ Can cool 160 litres of milk and maintain it at 4°C for at least 14 to 18 hours

Solar Refrigerators / Freezers

- There are various manufaturers that offer solar refrigerators or freezers with natural refrigerants (mainly R600a) for commercial or domestic refrigeration
- Case study Palfridge / The Fridge Factory in Eswatini)
- Solar R600a commercial or domestic 12 Volt solar models (107 or 199 litres capacity)



© SolarChill

Solar Direct Drive (SDD) coolers/freezers for medicine or vaccine

- In January 2025 the Performance, Quality and Safety (PQS) catalogue of the WHO contained 44 units:
  - 43 contained R-600a or R290
  - 1 unit did not contain any refrigerant

- Need to sustain 2°C to +8°C for up to 72 hours without external power supply.

- Available with freezer (ice packs)

- Be careful regarding HFO blowing agents!

Insulation materials

- Foaming agents in refrigeration provide essential thermal insulation for energy efficiency and cost savings
- Many foaming agents still use HCFCs like R141b, which have high GWP and ozone depletion potential
- More insulation materials come with HFO blowing agents (e.g. MF345) that contain PFAS and are harmful for the environment and humans
- Lack of proper disposal options for these foams leads to significant emissions at the end of equipment life
- Environmentally friendly alternatives with ultra-low GWP, such as hydrocarbons and liquid CO_2, are available and increasingly adopted

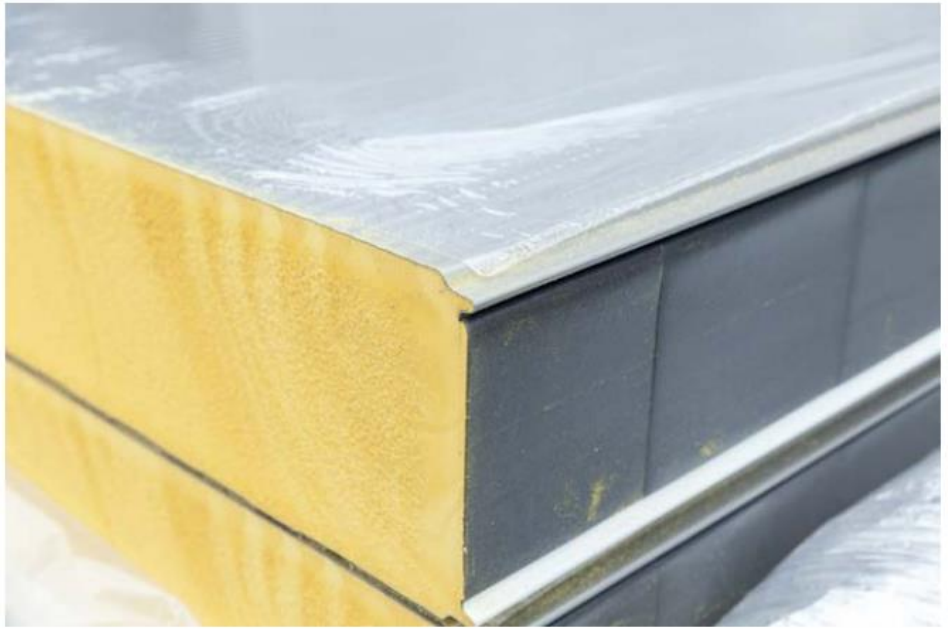


Photo 16: Insulating foam panels,
© DJ Srki/shutterstock.com

Climate- and Environmentally-friendly Solar Air Conditioning

Solutions and Case Studies

Solar Chillers in Jordan

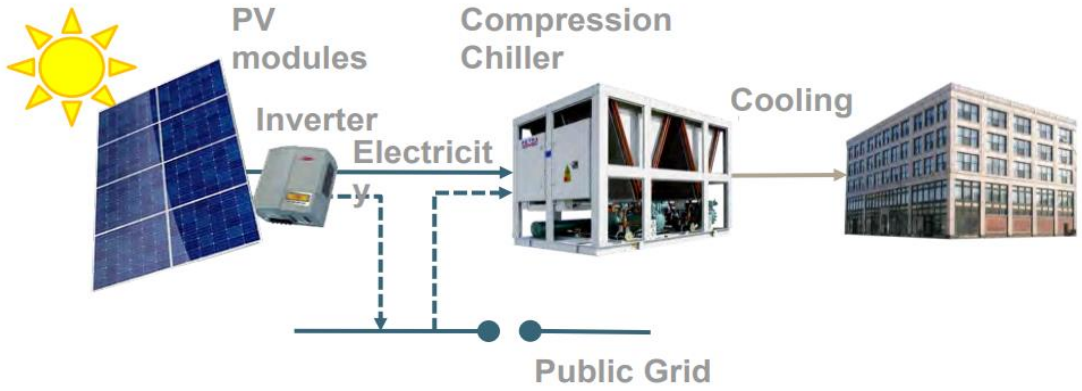
Compression chiller with PV

- 50kW capacity
- Using R290 as refrigerant

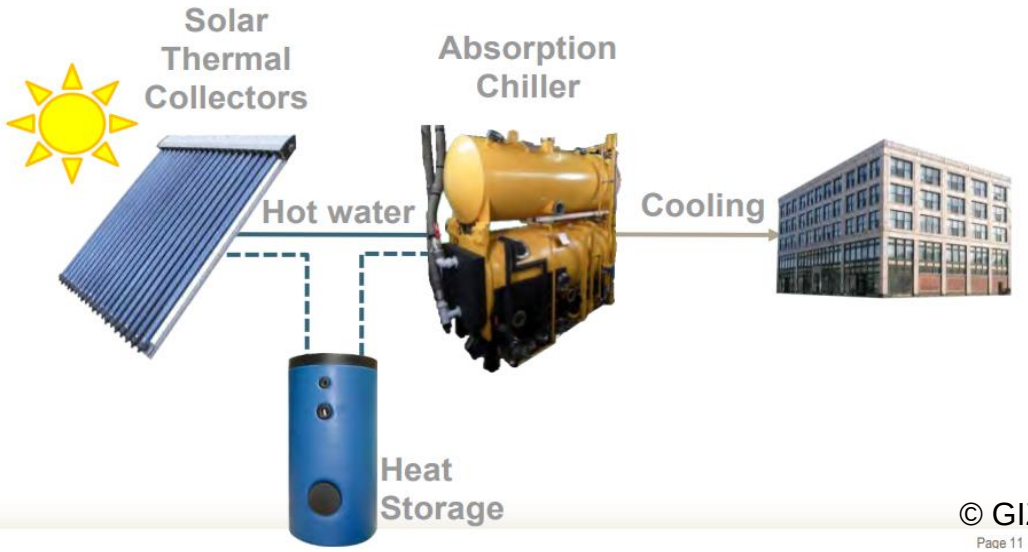
Absorption chiller with thermal solar collectors

- Directly transforming thermal energy into cold
- 160kW capacity
- Refrigerant typically used is a lithium bromide and water solution
- Higher upfront cost than PV systems → Only cost-effective for larger systems above 10kW capacity

Compression Chiller combined with PV

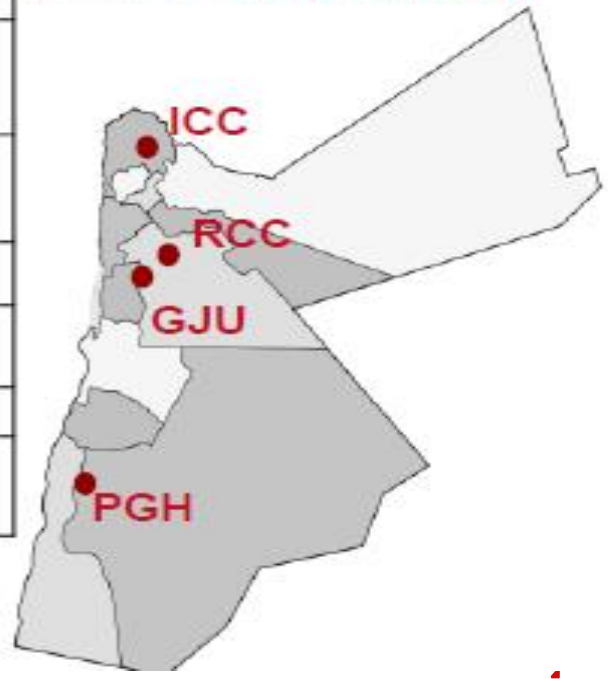


Absorption Chiller with Thermal



Solar Cooling Systems in Jordan

	German Jordan University (GJU)	Petra Guest House (PGH)	Royal Culture Center (RCC)	Irbid Chamber of Commerce (ICC)
				
solar system	solar heat for heating- & DHW / AbC Compound Parabolic Collectors (CPC)			
	150 CPC, 480m²gross	114 CPC, 388m²gross	132 CPC, 449m²gross	41 CPC, 140m²gross
heat storage	4 x 3,5m³ for heating *hydraulically decoupled*	4 x 3m³ for heating/cooling *hydraulically coupled*	3 x 3m³ for heating *hydraulically coupled*	1 x 3m³ for heating *hydraulically coupled*
chiller(s)	TUB absorption chiller - type bumblebee (FM160V021)			TUB AbC type Bee (FM050V021)
	1 / 2 direct air cooled compression chillers			
reject heat device	dry cooler - GEA V-Bank type			
cooling load	operating temperatures 6,7 - 9°C to 14°C			
	8 to 16	24h/7d design: 8-12 am + 6-12pm	8-24	8-16



AKA Typ bumblebee (160kW) Bee (50kW)

Air-Conditioning Chiller Powered Mainly by PV in Ghana

Installation of the first climate and environmentally friendly Air-Conditioning (AC) chiller in entire Africa installed at the nearly Zero Emission Building (nZEB) in Accra

- Cooling capacity of **115 kW**
- Natural refrigerant **R290**
- Entire building and its chiller mainly **(88%) powered by the 50 kWp PV system** on the roof
- With **50% less environmental impact**, compared to similar buildings constructed with traditional materials

© GIZ Ghana

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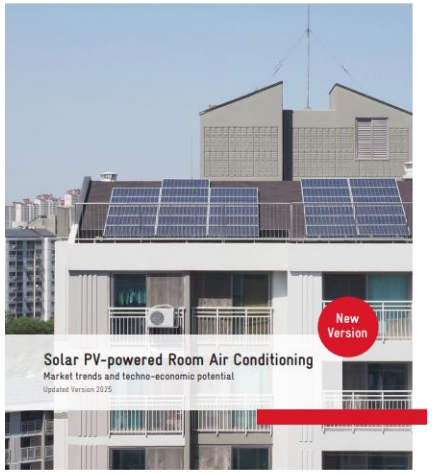
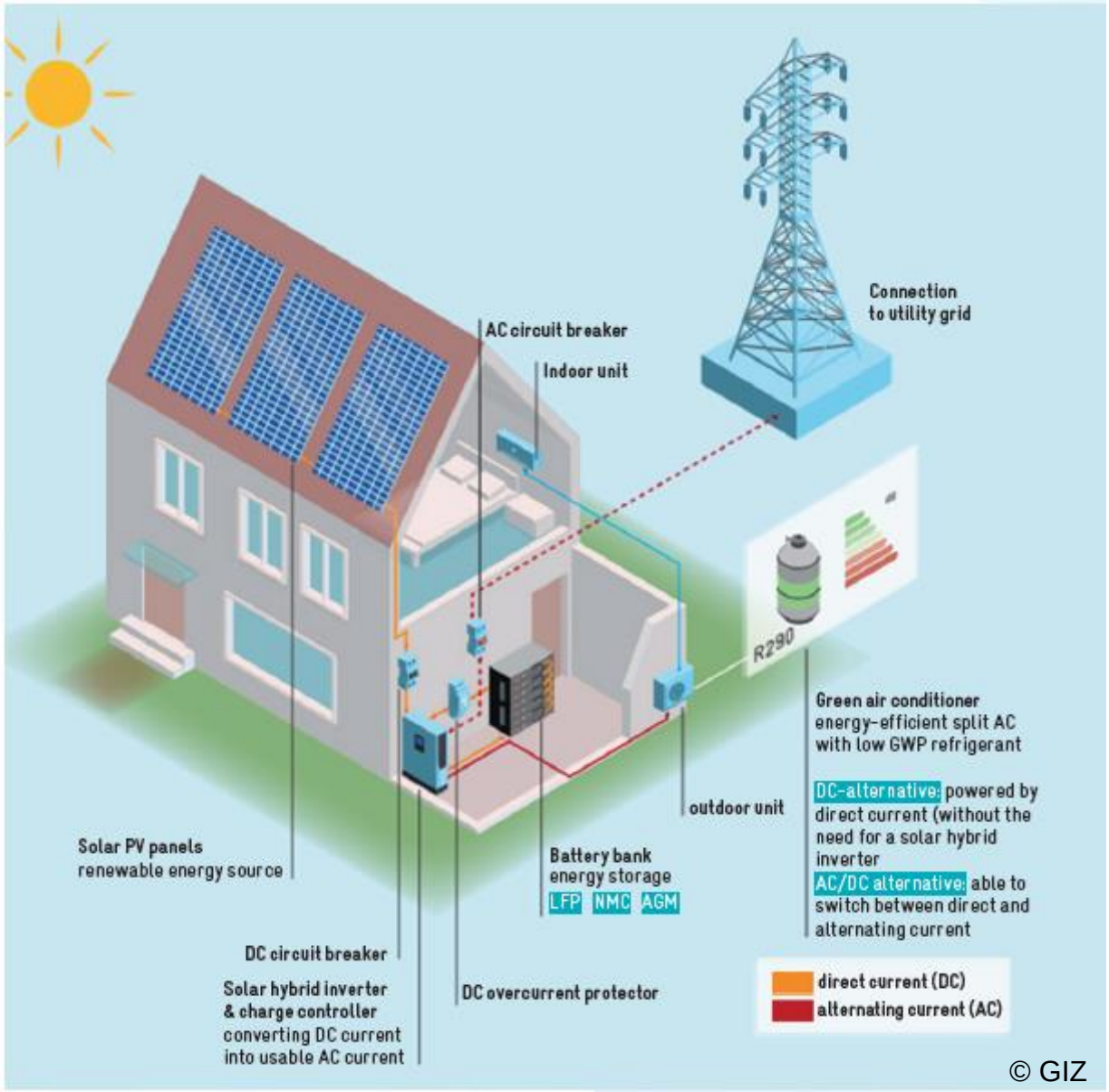
Chillers, that combine energy efficiency and natural refrigerants can reduce the total emissions by **40% in industrialised countries** and by **up to 60% in the Global South**, not considering renewable energy sources.

Solar PV and Split Air-Conditioners

- Single-split ACs account **for 70%** of all ACs used for space cooling
- Solar panels coupled with air-conditioning systems can be installed completely off-grid or in a hybrid mode





SelfChill: R290 split AC Powered by Individual PV System

Data	On-grid	Off-grid day	Off-grid night
Power Source	220-240V~40-63 Hz, 1 Ph	220-240V~40-63 Hz, 1 Ph	220-240V~40-63 Hz, 1 Ph
PV Capacity	2.3 kWp	3.0 kWp	3.8 kWp
PV Voltage	38.6 V	38.6 V	38.6 V
PV Current	9.1 A	9.1 A	9.1 A
Battery capacity	n.a.	4 x 125 Ah AGM 12 V	4 x 240 Ah AGM 12 V
Autonomy	n.a.	4 h	8 h
Inverter Power	5 kW	5 kW	5 kW
Cooling Capacity	12000 Btu/h	12000 Btu/h	12000 Btu/h
Heating Capacity	13000 Btu/h	13000 Btu/h	13000 Btu/h
Max. electrical power	3.50 kW	3.50 kW	3.50 kW
Seasonal Efficiency Ratio (SEER)	8.50 Btu/hW	8.50 Btu/hW	8.50 Btu/hW
Efficiency Ratio for Cooling at 20°C	16.43 Btu/hW	16.43 Btu/hW	16.43 Btu/hW
Efficiency Ratio for Cooling at 35°C	3.63 Btu/hW	3.63 Btu/hW	3.63 Btu/hW
Refrigerant and charge	R290 (380g)	R290 (380g)	R290 (380g)
GWP 100 / GWP 20 (6AR)	0.02 / 0.072	0.02 / 0.072	0.02 / 0.072
Sound Power Level	50-58 dB(A)	50-58 dB(A)	50-58 dB(A)

Green ACs Powered by Centralized PV system in Uganda

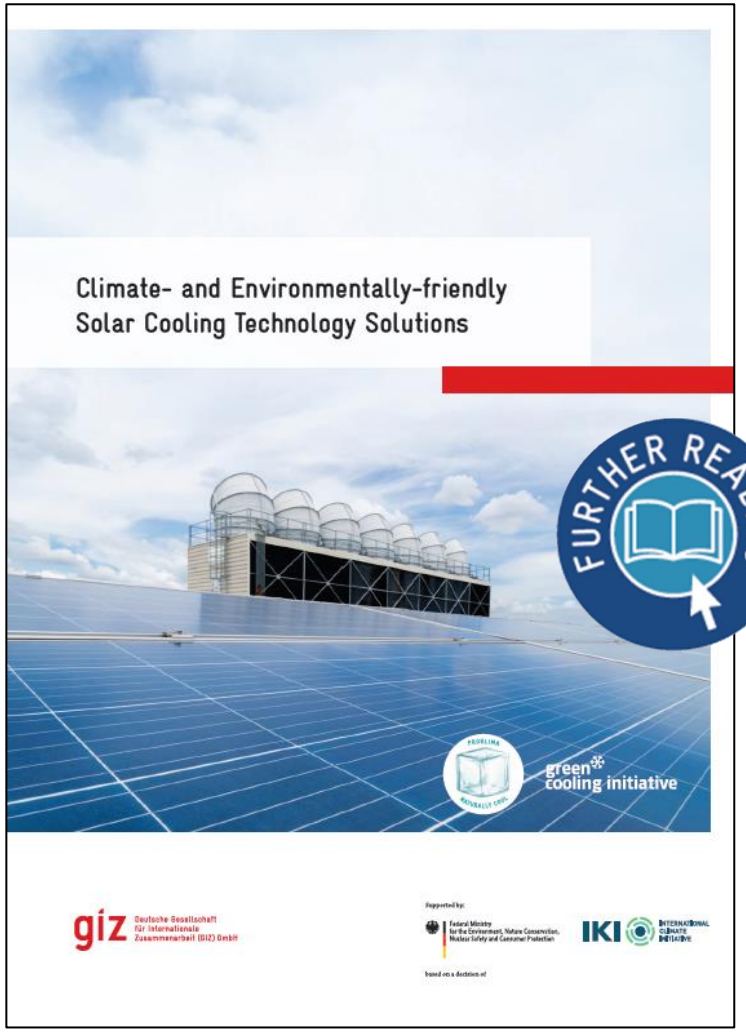
GIZ Uganda Country Office

- **18 efficient ACs**, with an **A+++** energy efficiency rating using **R290**
- **ACs have Eco Label (Blue Angel)**
- Replaced old inefficient fixed speed AC units utilizing synthetic refrigerants **R22** or **R410A**
- Run by a **40 kWp PV** system which also supplies the electric charging station for the GIZ electric car, as well as other electricity demand for lights and computers of the country office
- Project has been awarded by the GIZ Sustainability Award 2023

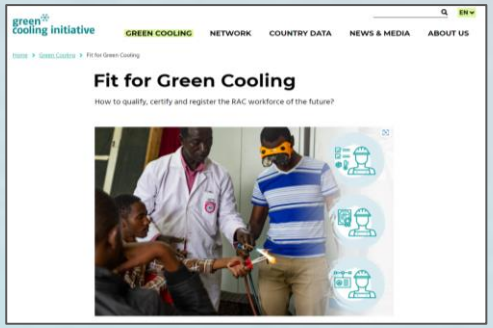
Conclusions

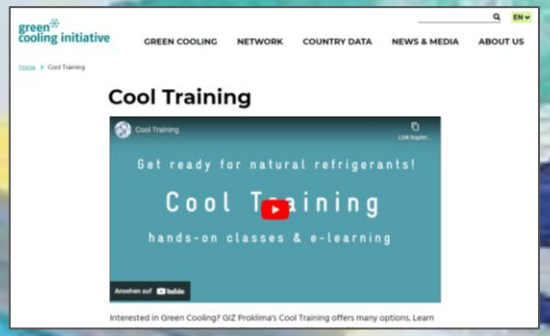
For a solar cooling system to be truly sustainable and climate-friendly, the technology should be:

- **F-gas and PFAS free,**
- **utilize ultra-low GWP natural refrigerants (e.g. R290, R600a, CO2 or NH3) for cooling systems,**
- **use ultra-low GWP natural blowing agents for the insulation material/panels (e.g. cyclopentane),**
- **ideally incorporate thermal energy storage systems (e.g. ice banks).**



Qualification, Certification, Registration (QCR) of Technicians is a MUST! Only trained & certified technicians are allowed to work on RAC equipment!





Fit for Green Cooling

Fit for Green Cooling: QCR of RAC Technicians (Video)

Cool Training

Free E-Learning Course

Proklima Publications (Selection)

All Proklima materials: www.green-cooling-initiative.org

SCAN ME

Green Cooling Network

- aims to promote green cooling technologies
- connects key players in the RAC sector such as gov't institutions, international organizations, and the private sector
- provides information, advice and collaboration opportunities to its members
- members are all committed to green cooling

Join the Green Cooling Network today!

www.green-cooling-initiative.org/network

Contact Information

Philipp Denzinger
Project Manager
GIZ Proklima International

philipp.denzinger@giz.de
www.green-cooling-initiative.org

www.giz.de

gizgmbh

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Registered offices, Bonn and Eschborn

Friedrich-Ebert-Allee 32 + 36
53113 Bonn, Germany
T +49 228 44 60 - 0
F +49 228 44 60 - 17 66

Dag-Hammarskjöld-Weg 1 - 5
65760 Eschborn, Germany
T +49 61 96 79 - 0
F +49 61 96 79 - 11 15

E info@giz.de
I www.giz.de

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Questions & Answers

Mark you calendars!

green cooling webinars

30 September, 14-15h CEST

Females for Future: Women in the Cooling Sector

More information coming soon!

giz

Contact

Thank you for your participation!
Please do not hesitate to contact us with any concerns, questions or requests.

Green Cooling Initiative III
proklima@giz.de

www.giz.de
www.green-cooling-initiative.org

www.linkedin.com/company/greencoolingbyproklima

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Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Registered offices, Bonn and Eschborn

Friedrich-Ebert-Allee 32 + 36
53113 Bonn, Germany
T +49 228 44 60 - 0
F +49 228 44 60 - 17 66

Dag-Hammarskjöld-Weg 1 - 5
65760 Eschborn, Germany
T +49 61 96 79 - 0
F +49 61 96 79 - 11 15

E info@giz.de
I www.giz.de

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH